

REMARKS

This responds to the Office Action dated June 11, 2002 in the case. Claims 3-6, 9, 12-15, 20-23, and 26 have been amended. Claims 1, 2, 10, 11, 18, 19 have been canceled without prejudice. Upon entry of this amendment, claims 3-9, 12-17, and 20-28 will be pending. Reconsideration of the application in view of the above amendments and the following remarks is respectfully requested. The issues raised by the Examiner are addressed next in the order in which they appear in the Office Action.

Drawings

In paragraph 1 of the Office Action the Examiner objected to the drawings under 37 C.F.R. § 1.84(p)(5), because Figures 3 and 6 include a reference character "z" not mentioned in the description. Correction was required.

Applicant respectfully submits that the character "z" in Figs. 3 and 6 is merely a label for the axis along which the tool is moving. As such it is provided merely to assist the reader, but does not refer to an object or an event that is described in the application. Nonetheless, in response to the Examiner's request for correction, applicant has amended the specification. In particular, applicant has amended the third paragraph on page 6 of the application, referring to Fig. 3, to recite that the "top portion of the figure illustrates single-event echo train obtained from a tool moving in the direction z." The second full paragraph on page 7, which refers to Fig. 6, has been amended similarly to recite "With reference to the notations in Fig. 3, the time-domain approach to enhancing vertical resolution of data logs in accordance with the present invention is illustrated in Fig. 6." The amendments add no new matter, as they merely state explicitly the implicit axis labels in Fig. 3 and Fig. 6, and are believed at the same time to respond to the Examiner's request for correction.

Applicant respectfully requests that the amendments of the specification identified above be approved by the Examiner, and that the corresponding objections to the drawings be withdrawn.

Claim Rejections Under 35 U.S.C. § 112

In paragraph 2 of the Office Action, claims 1-9, 17, 25, and 27 were rejected under 35 U.S.C. § 112, second paragraph, as being indefinite. In particular, the Office Action indicated that the language of claim 1 is unclear as to the type of measurement being made and the type of attributes being measured. The Office Action also indicated that in claims 8, 17, 25 and 27 it is unclear which type of porosity is referred to by the use of the porosity notation in the respective formulas. Applicant respectfully traverses.

With respect to the rejection of claim 1 and 2-9, which depend thereon, applicant submits that the proposed method does not rely on using a specific measurement, or deriving of specific types of attributes. All that is required in accordance with the claimed method is to derive a time-domain signal that is indicative of attributes of the material. As indicated in the specification of this application (*see e.g.*, pg. 8), such time-domain signals may be NMR logging signals, laboratory measurements, and various types of logging measurements usually associated with relatively low signal to noise ratio (SNR). Because the measurement approach used in accordance with this invention does not depend on the specific type of measurement made or on the attributes sought to be determined, applicant respectfully submits that reciting such features in the claims would unnecessarily limit the scope of the claims and therefore should not be required.

With respect to the rejection of claim 8, 17, 25, and 27 applicant submits that the proposed method does not rely on a specific type of porosity and can be readily implemented using any suitable method for computing formation porosity that depends on the measurement of time-domain signals. In a particular embodiment, the porosity referred to in the application as $\phi(T_2)$, is the NMR-derived porosity (or population) of the pores corresponding to the exponential decay time T_2 (*see e.g.*, pg. 6). Such NMR-derived porosity can, for example, correspond to a total porosity, effective porosity, clay-bound porosity, capillary porosity, free-fluid porosity or any other known NMR-based porosity determination. As known in the art, NMR-based porosity may further correspond to water, oil, or gas formation fluid components. Applicant respectfully submits that a person of skill in the art will readily appreciate that the approach defined in the subject claims does not

depend on the specific type of porosity ϕ (T_2), which can be adjusted dependent on the practical application.

Accordingly, applicant respectfully requests that the Section 112 claim rejections be withdrawn.

Claim Rejections Under 35 U.S.C. § 102(b)

In paragraph 3 of the Office Action, claims 1, 2, 4-11, 13-19 and 21-28 were rejected under 35 U.S.C. § 102(b) as being anticipated by U.S. Patent No. 6,005,389 to Prammer et al. (hereafter “’389 patent”).

In the interest of expediting the prosecution of the claims, applicant has canceled claims 1, 2, 10, 11, 18, and 19 without prejudice, and therefore the rejection is now moot. Applicant reserves the right to prosecute one or more continuation applications directed to the subject matter of the canceled claims, as well as additional subject matter disclosed in this application. Applicant’s decision to cancel these claims for expedience should not be interpreted as an agreement with the positions stated in the Office Action.

In addition, as also discussed in the following section, applicant has amended claims 3-6, 9, 12-15, 20-23 and 26. In particular, claims 3, 12, and 20 have been rewritten in independent format and as such retain their original scope. Claims 4, 5, 9, 13-15, 22, and 23 have been rewritten to respectively depend from independent claims 3, 12, and 20. Marked up versions of all amended claims, showing insertions and deletions, are attached hereto as Appendix B. Appendix C contains clean version of the all claims that will be pending upon entry of this amendment. The following section contains additional comments pertinent to the Section 102 rejection as well.

Claim Rejections Under 35 U.S.C. § 103(a)

In paragraph 4 of the Office Action, claims 3, 12, and 20 were rejected under 35 U.S.C. 103(a) as being unpatentable over the ’389 patent in view of U.S. Patent No. 5,163,153 to Reiderman et al. (hereafter “’153 patent”). As noted by the Examiner, the ’389 patent does not teach that “at least two of said one or more time intervals Δ_i are different.” But the Office Action stated that the ’153 patent teaches “varying the duration of the time intervals” in support of the assertion that the “it would have been obvious to one of ordinary

skill in the art to vary the time intervals in order to minimize the power consumption of the device while maintaining a maximum signal-to noise ratio.” Applicant respectfully traverses.

The Office Action admits that the '389 patent does not teach that “at least two of said one or more time intervals Δ_i are different.” The '153 patent is directed to acquiring NMR measurements of a materials using a pulse sequence that optimizes instrument electrical power usage. In particular, the patented method uses a first and second radio frequency (RF) magnetic fields in the material to reorient nuclear magnetic spins. NMR signals are detected after inducing the second radio frequency magnetic field. Applying the first and second magnetic fields is then repeated and the detected signals are stacked. The second RF magnetic field in accordance with the '153 patent has a duration and amplitude selected to reorient the nuclear magnetic spins by an angle selected to provide the stacked signal with improved signal to noise ratio compared to a single signal. (See Abstract of the disclosure, and the Summary of the invention). Specifically, the '153 system modifies the typical CPMG pulse sequence in a manner that reduces the amount of consumed power, making possible the generation of additional spin echo sequences that, when stacked together, improve the signal-to-noise ratio. (Col. 4, l. 54-64). Specific expressions for optimizing the power consumption are given for different “flip” angles of orientation applied for the second RF magnetic field. (See generally Col. 5, l. 46 to col. 7, l. 39).

Pertinent to the present case, applicant first notes that while the '153 patent discloses varying time intervals, this is done solely with reference to the flip angle degree of individual pulses in a sequence. In particular, instead of using 180° flip angles for what the patent refers to as “B-pulses” (as in a standard CPMG sequence), the patent proposes using a different angle α , the value of which may be optimized using the expression in Eq. (1) at col. 5. In other words, the patent discloses changing the duration of individual pulses.

By contrast, the subject claims require signal averaging over two or more different “time intervals Δ_i ” in a data train. The different time intervals Δ_i in applicant’s invention thus contain different numbers of pulses, not pulses with different flip angles.

Second, the subject claims require “constructing a time-domain averaged data train from said signal, the averaging being performed over two or more time intervals Δ_i , wherein at least two of said two or more time intervals Δ_i are different.” There is no such disclosure or teaching in the ’153 patent.

In particular, applicant respectfully submits that keeping of a desired level of the signal to noise ratio in the ’153 is done by “stacking” of different pulse sequences, not by averaging over different time intervals in the same pulse sequence. Specifically, as the ’153 patent explains, stacking involves superimposing different spin echo trains, which could be done by either using measurement sequences separated in time (such as a wait intervals of about five times T1 value), or using multiple frequencies to take simultaneous measurements in different excitation volumes. Col. 5, l. 24-45.

By contrast, the present invention does not depend on stacking of different pulse sequences at all. Applicant’s invention involves time-domain averaging of the signal in different time intervals in a single data sequence to increase the signal-to-noise ratio. (See, page 4, lines 27-35; page 7, lines 9-35). Note in particular the discussion in the background section of this application, which specifically discusses pulse stacking and the potential problems with it in situations where high logging speeds are desirable, such as reducing the apparent spatial resolution of measurements beyond the intrinsic resolution of the NMR tool. (See, page 3, lines 27-35 of the patent application, and Fig. 3).

Accordingly, the ’153 patent does not teach, disclose or even suggest time-domain averaging of a single data sequence over variable length time intervals to increase its signal-to-noise ratio. In particular, it does not even suggest constructing a time-domain averaged data train from a signal, the averaging being performed over two or more time different time intervals Δ_i , as recited in claim 3, 12 or 20.

For at least the reasons set forth in the above discussion, claims 3, 12, and 20 are patentable over the prior art of record. Accordingly, applicant respectfully requests that the section 103(a) claim rejection to be withdrawn.

Claims 4-9 depend from amended claim 3, claims 13-17 depend from amended claim 12, claims 21-25 depend from amended claim 20, and are thus believed to be patentable as well. Accordingly, applicants respectfully request that the art rejections be withdrawn.

SUMMARY

On the basis of the above, it is respectfully submitted that this application is in condition for allowance. A prompt action by the Examiner to this effect is respectfully requested. Should the Examiner have any questions or comments concerning this submission, or any aspect of the application, the Examiner is respectfully invited to call the undersigned at the phone number listed below.

A petition for extension of time for 2 months is attached, accompanied by the required fee. No other fee is believed due at this time. Should any fee be required, please charge the required fee to Pennie & Edmonds LLP Deposit account No. 16-1150.

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Respectfully submitted,

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Enclosures



APPENDIX A

MARKED-UP VERSION OF THE REVISED PARAGRAPHS IN THE SPECIFICATION OF U.S. PATENT APPLICATION SER. NO. 09/803,819

The third paragraph on page 6 of the application:

To reduce the effect of random noise, it is commonly practiced to stack echo-trains from a multiple number of events. Fig. 3 illustrates the basic idea behind stacking. The top portion of the figure illustrates single-event echo train obtained from a [moving] tool moving in the direction z having a given intrinsic vertical resolution determined primarily by the dimensions of the tool. The bottom portion of the figure shows the effect of multi-event stacking, which clearly reduces the noise considerably, but also acts to change the apparent vertical resolution of the tool.

The second full paragraph on page 7 of the application:

With reference to the notations in Fig. 3, the [The] time-domain approach to enhancing vertical resolution of data logs in accordance with the present invention is illustrated in Fig. 6. In particular, in accordance with the present invention the following approach is used. First, construct a time domain averaged echo train as follows: for time t , take an average of echos over a time interval Δ , as defined by the following expression:



APPENDIX B

MARKED-UP VERSION OF THE CLAIMS IN THE U.S. PATENT APPLICATION SER. NO. 09/803,819

3. (Amended) A method for measuring an indication of attributes of materials containing a fluid state, the method comprising the steps of:

providing a time-domain signal indicative of attributes of said materials in a single measurement;

constructing a time-domain averaged data train from said signal, the averaging being performed over two or more time intervals Δ_i , [The method of claim 1] wherein at least two of said [one] two or more time intervals Δ_i are different; and

computing an indication of attributes of said materials from the time-domain averaged data train.

4. (Amended) The method of claim [2] 3 wherein the following expression is used to construct the time-domain averaged data train:

$$S_{\Delta}(t) = \int_t^{t+\Delta} dt' S(t') / \Delta$$

where $S_{\Delta}(t)$ is the provided time-domain signal.

5. (Amended) The method of claim [1] 3, wherein the interval Δ_i is [fixed] variable and the time-domain averaged data train is constructed at times $t = t_0, t_0 + \Delta, t_0 + 2\Delta, \dots, t_0 + N\Delta$.

6. (Amended) The method of claim [1] 3, wherein the time-domain signal is an NMR echo train.

9. (Amended) The method of claim [1] 3 further comprising the step of averaging two or more constructed time-domain averaged data trains to increase the signal-to-noise ratio (SNR) of the measurement.

12. (Amended) A method for measuring an indication of attributes of materials containing a fluid state, comprising the steps of:

providing an NMR echo-train indicative of attributes of materials along the borehole;

constructing a time-domain averaged data train from said NMR echo train, the averaging being performed over two or more time intervals Δ_i , [The method of claim 10] wherein at least two of said [one] two or more time intervals Δ_i are different; and

computing an indication of attributes of said materials from the time-domain averaged data train.

13. (Amended) The method of claim [10] 12 further comprising the step of averaging two or more constructed time-domain averaged data trains to increase the signal-to-noise ratio (SNR) of the measurement.

14. (Amended) The method of claim [10] 12 wherein the following expression is used to construct the time-domain averaged data train:

$$Echo_{\Delta}(t) = \int_t^{t+\Delta} dt' Echo(t') / \Delta$$

where $Echo_{\Delta}(t)$ is the provided time-domain signal over a time interval Δ_i .

15. (Amended) The method of claim [10] 12, wherein the time interval Δ_i is [constant] variable and the time-domain averaged data train is constructed at times $t = t_0, t_0 + \Delta, t_0 + 2\Delta, \dots, t_0 + N\Delta$.

20. (Amended) A method for increasing the spatial resolution of NMR logging measurements, comprising the steps of:

providing an NMR echo-train indicative of attributes of materials of interest; and
constructing a time-domain averaged data train from said NMR echo train, the
averaging being performed over two or more time intervals Δ_i , [The method of claim 18]
 wherein at least two of said [one] two or more time intervals Δ_i are different.

21. (Amended) The method of claim [18] 20 further comprising the step of averaging two or more constructed time-domain averaged data trains to increase the signal-to-noise ratio (SNR) of the measurement.

22. (Amended) The method of claim [18] 20 wherein the following expression is used to construct the time-domain averaged data train:

$$Echo_{\Delta}(t) = \int_t^{t+\Delta} dt' Echo(t') / \Delta$$

where $Echo_{\Delta}(t)$ is the provided time-domain signal.

23. (Amended) The method of claim [18] 20 wherein the time interval Δ_i is [constant] variable and the time-domain averaged data train is constructed at times $t = t_0, t_0 + \Delta, t_0 + 2\Delta, \dots, t_0 + N\Delta$.

26. (Amended) A method for real-time processing of NMR logging signals, comprising the steps of:

providing real-time data corresponding to a single-event NMR echo train indicative of physical properties of materials of interest;

constructing a time-domain averaged data train from said NMR echo train, the averaging being performed over variable time interval Δ using the expression

$$S_{\Delta}(t) = \int_t^{t+\Delta} dt' S(t') / \Delta$$

where $S(t)$ is the provided measurement signal, and the time-domain averaged data train is constructed at times $t = t_0, t_0 + \Delta, t_0 + 2\Delta, \dots, t_0 + N\Delta$; and

computing in real time an indication of the physical properties of said materials based on the constructed time-domain averaged data train.



APPENDIX C

THE CLAIMS THAT WILL BE PENDING UPON ENTRY OF THE PRESENT AMENDMENT

3. A method for measuring an indication of attributes of materials containing a fluid state, the method comprising the steps of:

providing a time-domain signal indicative of attributes of said materials in a single measurement;

constructing a time-domain averaged data train from said signal, the averaging being performed over two or more time intervals Δ_i , wherein at least two of said two or more time intervals Δ_i are different; and

computing an indication of attributes of said materials from the time-domain averaged data train.

4. The method of claim 3 wherein the following expression is used to construct the time-domain averaged data train:

$$S_{\Delta}(t) = \int_t^{t+\Delta} dt' S(t') / \Delta$$

where $S_{\Delta}(t)$ is the provided time-domain signal.

5. The method of claim 3, wherein the interval Δ_i is variable and the time-domain averaged data train is constructed at times $t = t_0, t_0 + \Delta, t_0 + 2\Delta, \dots, t_0 + N\Delta$.

6. The method of claim 3, wherein the time-domain signal is an NMR echo train.

7. The method of claim 6, wherein the step of computing an indication of attributes is performed using inversion of the constructed time-domain averaged data train into T_2 domain.

8. The method of claim 7, wherein the T_2 distribution is estimated using the following expression

$$S_{\Delta}(t) = \sum_{T_2} \phi(T_2) \exp(-t / T_2) (1 - \exp(-\Delta / T_2)) + Noise$$

where $\phi(T_2)$ is the porosity corresponding to the exponential decay time T_2 .

9. The method of claim 3 further comprising the step of averaging two or more constructed time-domain averaged data trains to increase the signal-to-noise ratio (SNR) of the measurement.

12. A method for measuring an indication of attributes of materials containing a fluid state, comprising the steps of:

providing an NMR echo-train indicative of attributes of materials along the borehole;

constructing a time-domain averaged data train from said NMR echo train, the averaging being performed over two or more time intervals Δ_i , wherein at least two of said two or more time intervals Δ_i are different; and

computing an indication of attributes of said materials from the time-domain averaged data train.

13. The method of claim 12 further comprising the step of averaging two or more constructed time-domain averaged data trains to increase the signal-to-noise ratio (SNR) of the measurement.

14. The method of claim 12 wherein the following expression is used to construct the time-domain averaged data train:

$$Echo_{\Delta}(t) = \int_t^{t+\Delta} dt' Echo(t') / \Delta$$

where $Echo_{\Delta}(t)$ is the provided time-domain signal over a time interval Δ_i .

15. The method of claim 12, wherein the time interval Δ_i is variable and the time-domain averaged data train is constructed at times $t = t_0, t_0 + \Delta, t_0 + 2\Delta, \dots, t_0 + N\Delta$.

16. The method of claim 15, wherein the step of computing an indication of attributes is performed using inversion of the constructed time-domain averaged data train into T_2 domain.

17. The method of claim 16, wherein the T_2 distribution is estimated using the following expression

$$Echo_{\Delta}(t) = \sum_{T_2} \phi(T_2) \exp(-t / T_2) (1 - \exp(-\Delta / T_2)) + Noise$$

where $\phi(T_2)$ is the porosity corresponding to the exponential decay time T_2 .

20. A method for increasing the spatial resolution of NMR logging measurements, comprising the steps of:

providing an NMR echo-train indicative of attributes of materials of interest; and constructing a time-domain averaged data train from said NMR echo train, the averaging being performed over two or more time intervals Δ_i , wherein at least two of said two or more time intervals Δ_i are different.

21. The method of claim 20 further comprising the step of averaging two or more constructed time-domain averaged data trains to increase the signal-to-noise ratio (SNR) of the measurement.

22. The method of claim 20 wherein the following expression is used to construct the time-domain averaged data train:

$$Echo_{\Delta}(t) = \int_t^{t+\Delta} dt' Echo(t') / \Delta$$

where $Echo_{\Delta}(t)$ is the provided time-domain signal.

23. The method of claim 20 wherein the time interval Δ_i is variable and the time-domain averaged data train is constructed at times $t = t_0, t_0 + \Delta, t_0 + 2\Delta, \dots, t_0 + N\Delta$.

24. The method of claim 23, wherein the step of computing an indication of attributes is performed using inversion of the constructed time-domain averaged data train into T_2 domain.

25. The method of claim 24 wherein the T_2 distribution is estimated using the following expression

$$Echo_{\Delta}(t) = \sum_{T_2} \phi(T_2) \exp(-t / T_2) (1 - \exp(-\Delta / T_2)) + Noise$$

where $\phi(T_2)$ is the porosity corresponding to the exponential decay time T_2 .

26. A method for real-time processing of NMR logging signals, comprising the steps of:

providing real-time data corresponding to a single-event NMR echo train indicative of physical properties of materials of interest;

constructing a time-domain averaged data train from said NMR echo train, the averaging being performed over variable time interval Δ using the expression

$$S_{\Delta}(t) = \int_t^{t+\Delta} dt' S(t') / \Delta$$

where $S(t)$ is the provided measurement signal, and the time-domain averaged data train is constructed at times $t = t_0, t_0 + \Delta, t_0 + 2\Delta, \dots, t_0 + N\Delta$; and

computing in real time an indication of the physical properties of said materials based on the constructed time-domain averaged data train.

27. The method of claim 26, further comprising the step of

inverting of the constructed time-domain averaged data train into the T_2 domain, wherein the T_2 distribution is modeled using the expression

$$Echo_{\Delta}(t) = \sum_{T_2} \phi(T_2) \exp(-t / T_2) (1 - \exp(-\Delta / T_2)) + Noise$$

where $\phi(T_2)$ is the porosity corresponding to the exponential decay time T_2 .

28. The method of claim 26, further comprising the step of averaging two or more constructed time-domain averaged data trains to increase the signal-to-noise ratio (SNR) of the measurement.